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Vitamin A  
Retinol  
Carotenoids  
 $\alpha$ -Carotene  
 $\beta$ -Carotene  
Lutein  
Zeaxanthin  
Lycopene

## The Contribution of Various Foods to Intake of Vitamin A and Carotenoids in the Netherlands

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**Summary:** *This study presents data on dietary intake of specific carotenoids in the Netherlands, based on a recently developed food composition database for carotenoids. Regularly eaten vegetables, the main dietary source of carotenoids, were sampled comprehensively and analysed with modern analytic methods. The database was complemented with data from recent literature and information from food manufacturers. In addition, data on intake of vitamin A are presented, which are based on the most recent update of the Dutch Food Composition Table. Intake of vitamin A was calculated for adult participants of the second Dutch National Food Consumption Survey in 1992, whereas intake of carotenoids was calculated for participants of the Dutch Cohort Study on diet and cancer, aged 55 to 69 in 1986. Mean intake of vitamin A amounted to 1.1 and 0.9 mg RE/day for men and women, respectively; the contributions of meat, fats and oils, vegetables and dairy products to total intake were 35%, 24%, 16%, and 16%, respectively. Mean intake of  $\alpha$ -carotene,  $\beta$ -carotene and lutein plus zeaxanthin was 0.7, 3.0, and 2.5 mg/day respectively for both men and women, while mean intake of lycopene was 1.0 mg/day for men and 1.3 mg/day for women. The most important foods contributing to intake of  $\beta$ -carotene and lutein plus zeaxanthin were carrots ( $\beta$ -carotene only), spinach, endive and kale.*

## Introduction

Recent interest in potential health effects of several carotenoids other than their contribution to vitamin A activity has stimulated the development of accurate databases for carotenoids in several countries, including the USA [1] and Finland [2, 3]. Since comprehensive data on carotenoids in Dutch foods – in particular vegetables as major sources – were lacking, we developed such a database for the Netherlands by 1. sampling and analysing the regularly consumed vegetables and 2. completing the database with recent data from the literature and information from food manufacturers. This paper presents data on intake of carotenoids in the Netherlands based on the new carotenoid database. For the sake of completeness, data on intake of vitamin A are also presented.

Representative food consumption data were available from the Dutch National Food Consumption Survey (DNFCS), while relatively recent vitamin A values of foods were available from the Dutch Food Composition Table [4]. Intake of specific carotenoids, however, could not be calculated with the Dutch Food Composition Table, as it does not yet include the newly derived values for specific carotenoids. Therefore, we calculated carotenoid intake from data available in the Dutch Cohort Study on Diet and Cancer (NLCS), for which a more limited food con-

sumption table is used and which includes the newly derived values for several carotenoids in foods.

## Subjects and methods

**Subjects and dietary assessment methods:** For calculations of vitamin A intake, we used the population studied for the DNFCS in 1992 [5, 6]. This survey comprised a representative probability sample of 2475 Dutch private households and included 6218 subjects aged 1 to 92. For the present purpose, data were used from the 1912 men and 2256 women aged 20 to 70. Information on food consumption was obtained using a two-day record. In each household the subject principally responsible for domestic matters recorded all the food and beverages supplied to the household members, as well as information on cooking methods, recipes and ingredients. All households members over 12 recorded the food eaten away from home in personal diaries.

For the calculation of carotenoid intake, we used a random sample (1525 men and 1598 women) from the participants of the NLCS [7], which was derived from a random sample from the Dutch population aged 55 to 69 in 1986. The participants completed a 150-item semi-quantitative food frequency questionnaire (FFQ), which assessed habitual food consumption during the year preceding September 1986 [8]. The FFQ covered virtually all vegetables eaten regularly in the Netherlands as well as most of the regularly eaten fruits.

**Food composition tables:** For calculations of vitamin A intake from the DNFCS in 1992, we used the Dutch Food Composition Table of 1996 [4], because in the 1996 table the retinol values for liver and liver products were updated and missing values were completed. The vitamin A value for all foods in the table is based on the algorithm  $[\text{retinol} + \beta\text{-carotene}/6]$  and expressed as retinol equivalents (RE; 1 RE is 1  $\mu\text{g}$  vitamin A or 6  $\mu\text{g}$   $\beta$ -carotene).

For calculations of intake of specific carotenoids, we made an entirely new food composition table. The foods mainly contributing to the intake of carotenoids, i.e. vegetables, were sampled and analysed for  $\alpha$ - and  $\beta$ -carotene, lutein, zeaxanthin and lycopene. Some other relatively important foods, such as margarines, were also analysed to check the data supplied by the manufacturers. Values for all other foods were mostly derived from recent literature based on the same methods of analysis as we used. Mangels *et al.*'s paper [1] was used to see whether a specific food contained a specific carotenoid. Various other sources were also used, in particular Heinonen *et al.* [2, 3], Hart *et al.* [9], Bureau *et al.* [10], and Holland *et al.* [11].

The vegetables analysed are listed in Table I. Each type of vegetable was sampled in two to three different periods across a year (1995/1996); for each vegetable the choice of the periods was based on size of supply and available varieties. For each sampling period, a pooled sample of the vegetable, obtained from seven different retailers, was assembled. This sample was cleaned and cut according to methods applied by most consumers and cooked vegetables were prepared according to cookery book guidelines. Samples were cooled down to 0 °C, homogenized for 20–30 s, immediately followed by freezing

Table I: Vegetables sampled for carotenoid analysis, Netherlands, 1995/1996

Beetroot	Endive
Brussels sprouts	Kale
Beans	Leek
broad	Lettuce
French	Spinach
runner	fresh
Cabbage	frozen
oxheart	green
savoy	red
white	Sweet peppers
Carrots	Tomatoes
fresh	
winter	

in liquid nitrogen. Samples were stored at –80 °C until analysis. After thawing, samples were extracted with methanol/tetrahydrofuran (1:1; v/v) using the "EC MAT common procedure" [12]. For analysis (which did not involve saponification) carotenoids were separated by reversed-phase HPLC (column: Nucleosil 3  $\mu\text{m}$ ; 125 mm  $\times$  4.6 mm; eluent: acetonitrile/methanol/dichloromethane/double-distilled water; 900:50:40:10; v/v) and quantified by absorbance measurement [12]. A reference sample containing spinach, tomatoes and carrots was used to check analytical conditions across the year. For each vegetable, the carotenoid values included in the new food composition table was based on consumption weighted values of the two or three pooled samples analysed.

**Calculation of intake and of food groups contributing to intake:** For the DNFCS, intake of vitamin A in RE (or  $\mu\text{g}/\text{day}$ ) was calculated from the consumption of foods averaged across the two record days. For the contribution of food groups to vitamin A intake, a standard food grouping was used [4]. For the purpose of comparison, vitamin A intake was also calculated with the 1993 Food Composition Table which did not yet include updated retinol values for liver and liver products [13].

For the NLCS, mean usual intake of  $\alpha$ - and  $\beta$ -carotene, lycopene and lutein plus zeaxanthin was calculated in  $\mu\text{g}/\text{day}$ . Lutein and zeaxanthin were taken together because most of the literature sources used did not provide separate values for each of these carotenoids. Vegetables, however, contain primarily lutein and only very minor quantities of zeaxanthin. A standard food grouping similar to the grouping used for DNFCS was used to calculate the contribution of foods to vitamin A intake.

## Results

Mean total vitamin A intake was 1.1 and 0.9 mg/day for men and women respectively. Figure 1 displays the main food groups contributing to

Table II: Mean daily carotenoid intake (mg/day) in men and women aged 55–69. NLCS 1986

	Men		Women	
	mean	SD	mean	SD
$\alpha$ -Carotene	0.69	0.56	0.71	0.60
$\beta$ -Carotene	2.98	1.56	2.97	1.61
Lutein + zeaxanthin	2.55	1.12	2.48	1.05
Lycopene	1.05	1.56	1.33	1.88

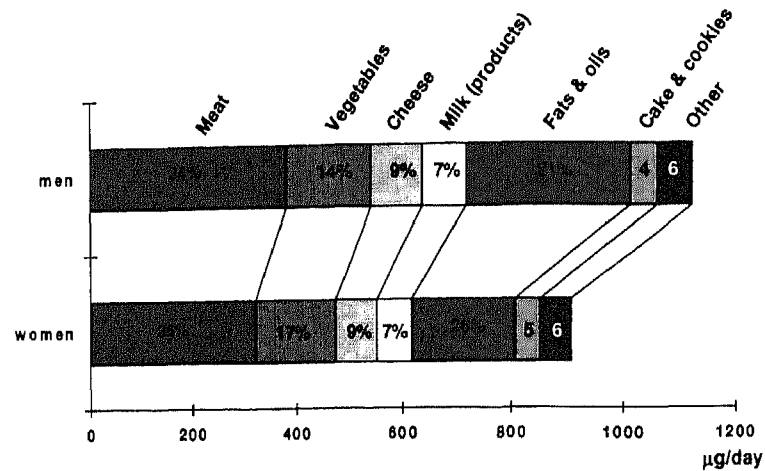


Figure 1: Contribution of food groups to vitamin A intake (RE) in Dutch adults. DNFCs (1992).

vitamin A intake. Meat accounted for one third of total intake and fats and oils for about a quarter. Other important contributing foods were vegetables and dairy products (each about 16%). Absolute vitamin A intake from meat was 382 µg/day for men and 324 µg/day for women. Using the outdated 1993 food table, these figures were 160 and 140 µg/day respectively, i. e. less than half of the true intake from meat.

Total intake of carotenoids is presented in Table II. The main carotenoids were  $\beta$ -carotene and lutein plus zeaxanthin, with a mean intake of 3.0 and 2.5 mg/day for both men and women respectively. The third carotenoid was lycopene, with a mean intake of 1.0 mg/day for men and 1.3 mg/day for women. Intake of  $\alpha$ -carotene was lower at 0.7 mg/day. Smoking status was (non-significantly) associated with  $\beta$ -carotene intake: the intake was 3.3 mg/day (men) and 3.1 mg/day (women) for never-smokers, 2.9 mg/day (men)

and 2.8 mg/day (women) for current smokers and 3.0 mg/day (men) and 2.9 mg/day (women) for former smokers. As the proportion of never-smokers was much higher among women (65%) than among men (10%), average intake was the same in men and women.

Table III shows the contribution of food groups to the intake of carotenoids. Vegetables accounted for two thirds or more of total intake for each of the carotenoids. Other substantial sources appeared to be soups, for which the recipes used prescribed substantial amounts of vegetables including carrots. Fresh tomatoes used for soups were included in the vegetable group, however. Tomato juice was an important source of lycopene.

The contribution of specific vegetables to the intake of  $\beta$ -carotene and lutein from vegetables is displayed in Figures 2 and 3 respectively. Carrots were the main source of  $\beta$ -carotene, fol-

Table III: Contribution of food groups to intake of carotenoids (mg/day). NLCS 1986, men and women combined

	$\alpha$ -Carotene		$\beta$ -Carotene		Lutein + zeaxanthin		Lycopene	
	mean	(%)	mean	(%)	mean	(%)	mean	(%)
Potatoes	—	—	—	—	0.08	(3)	—	—
Vegetables	0.47	(67)	2.07	(70)	1.96	(78)	0.78	(66)
Fruits	0.01	(1)	0.05	(2)	0.11	(4)	0.01	(1)
Bread	—	—	0.01	(0)	0.12	(5)	—	—
Eggs	—	—	—	—	0.10	(4)	—	—
Fats & oils	—	—	0.17	(6)	0.01	(0)	—	—
Soups	0.21	(30)	0.50	(17)	0.07	(3)	0.06	(5)
Non-alcoholic beverages	—	—	0.03	(1)	0.01	(0)	0.30	(25)
Other	0.01	(1)	0.14	(5)	0.05	(2)	0.04	(3)
Total	0.70	100	2.97	100	2.51	100	1.19	100

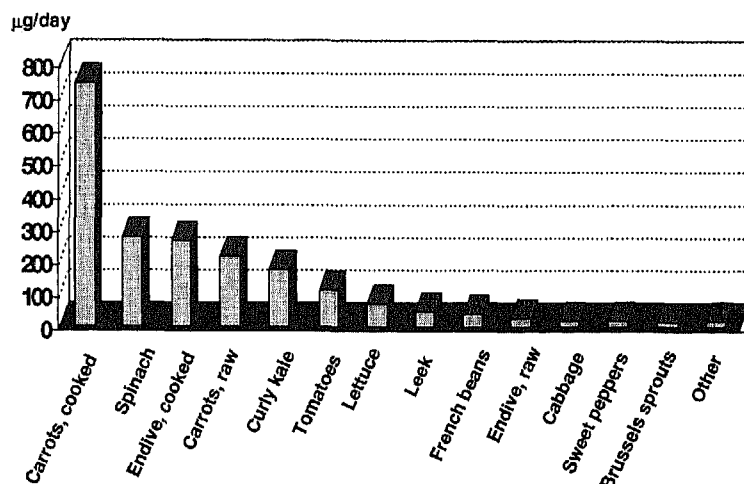


Figure 2: Contribution of specific vegetables to  $\beta$ -carotene intake. NLCS (1986).

lowed by green leafy vegetables such as spinach, endive and kale. These leafy vegetables were also the main sources of lutein (Fig. 3). All other vegetables contributed little (19%) to intake of  $\beta$ -carotene and somewhat more (33%) to the intake of lutein from vegetables. Of the intake of  $\alpha$ -carotene and lycopene from vegetables, 92% was derived from carrots (cooked, 71%; raw, 21%) and tomatoes respectively.

Finally, we compared the intake of  $\beta$ -carotene as calculated from our new carotenoid table with that based on vitamin A values derived from the Dutch Food Composition Table (Table IV). To make this comparison possible, we calculated the contribution of foods of vegetable origin (RE multiplied by 6). Although the intake of  $\beta$ -carotene appears to be higher when calculated from the new carotenoid table (3.0 versus 2.5 mg/day), the mean difference is limited, while the correlation between the old and new data is relatively high.

## Discussion

According to the updated Food Composition Table [4], mean daily intake of vitamin A exceeding 1.1 mg for men and more than 0.9 mg for women is higher than the Dutch recommended daily allowance (RDA) of 1 and 0.8 mg for adult men and adult women respectively. Some further increase in the estimate of vitamin A intake is to be expected after updating of the

Dutch Food Composition Table for the  $\beta$ -carotene values of vegetables.

The data presented on intake of carotenoids are the first data in the Netherlands calculated on the basis of a food composition table based on extensively sampled foods and modern methods of analysis. It is surprising that the intake of  $\beta$ -carotene calculated on the basis of the regular Dutch Food Composition Table, which was based on old data and old-fashioned methods of analysis, correlated rather well with the new data and only underestimated mean intake by 0.5 mg/day.

The estimated mean intake of carotenoids should be interpreted with some caution: it was based on a population aged 55 to 69 in 1986 and thus may not fully represent intake of today's population at large. Furthermore, a food frequency method, which slightly overestimated vegetable intake, was used to assess dietary patterns. Nevertheless, the data do allow global comparison with data on intake of carotenoids in other countries. In the USA, for example,

Table IV: Intakes of  $\beta$ -carotene (mg/day) and their correlation according to the old food composition table and the new carotenoid database

	Old*		New		<i>r</i> Spearman
	mean	SD	mean	SD	
Men	2.4	1.4	3.0	1.6	0.88
Women	2.6	1.4	3.0	1.6	0.89

\* Calculated from contribution of foods from vegetable origin to vitamin A intake (RE  $\times$  6) based on Dutch Food Composition Table 1986.

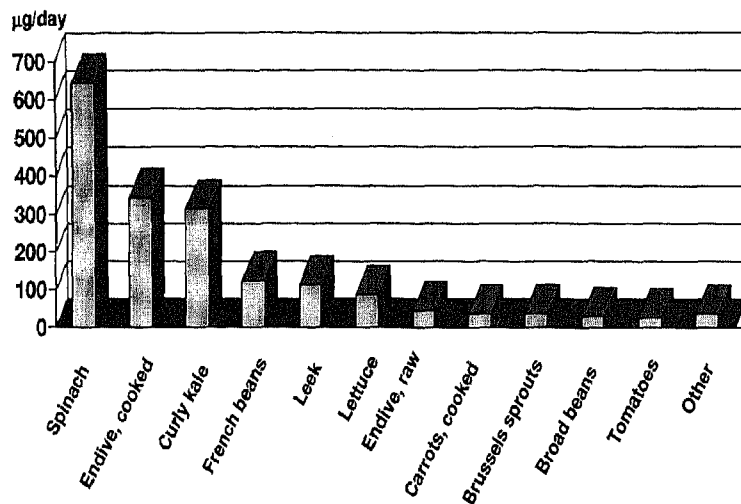


Figure 3: Contribution of specific vegetables to lutein intake, NLCS (1986).

where a carotenoid table of similar quality is available [1, 14], intake in a representative population amounted to 1.5, 0.8, and 3.5 mg/day for  $\beta$ -carotene, lutein plus zeaxanthin, and lycopene respectively [15]. Intake of  $\beta$ -carotene and lutein was much lower, whereas intake of lycopene was much higher than in the Netherlands. Using the same database, selected populations of nurses and health professionals had an intake of 5, 4, and 11 mg/day of  $\beta$ -carotene, lutein plus zeaxanthin, and lycopene respectively [16], i.e. much higher than in the Netherlands. In particular, lycopene intake is much lower in the Netherlands, apparently due to low consumption levels for tomato sauces, ketchup and Italian foods in the elderly population.

As expected, vegetables were the main sources of  $\beta$ -carotene and lutein. Besides carrots ( $\beta$ -carotene only) and spinach (both carotenoids), endive and kale appeared to be important sources of  $\beta$ -carotene and lutein in the Dutch population. Endive is a moderate source of both carotenoids but is eaten frequently. Kale contains large amounts of  $\beta$ -carotene and lutein but is eaten less frequently.

We have presented accurate data on dietary intake of carotenoids in the Netherlands. Future research activities should include extension of the present carotenoid database to the complete Dutch Food Composition Table. Furthermore, more data are needed to obtain good estimates of the bioavailability of each of the carotenoids.

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